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DRY ROT IN
FACTORY TIMBERS

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**INSPECTION DEPARTMENT
Associated Factory
Mutual Fire Insurance Companies,
31 Milk Street, Boston, Mass.**

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December 1, 1913.

**DRY ROT
IN
FACTORY TIMBERS.**

The object of this pamphlet is to call the attention of Mill Owners, Architects and Builders to the fact that the present supply of timber available for mill construction is subject to dangers, the neglect of which is resulting in serious consequences. Within three years more than \$100,000 have been required to repair damage due to Dry Rot in the cases which have come to our attention. Nearly all of the lumber affected was Southern hard pine in comparatively new buildings.

Fifteen or twenty cases have been carefully investigated, several thousand beams have been examined in place or after removal from infected mills. More than a hundred full-size sections of beams and columns have been examined chemically and microscopically. Fungus has been cultivated from about

one hundred specimens. Several hundred photographs and photomicrographs have been made. An abstract of the results of this work is contained in the following pages:

It is generally agreed that rot in wood is caused by growth in the cells of a lower order of plant called a fungus. A large variety of fungi can grow on wood under favorable conditions but only two or three are concerned in the destruction of mill timber. Two of the commonest are shown in Figures 14 and 15. A different class of fungi which destroys railway ties is rarely found in factory timber.

The cause of this rapidly increasing destruction is unquestionably the use of less resistant material than in former years. A lot of timber for the frame of a new mill is now rarely seen which is not mostly North Carolina, Cuban or Shortleaf pine. The best qualities of these varieties are undoubtedly as resistant as the Longleaf pine but they are less uniform and the poor qualities are much more difficult to detect by the necessarily superficial acceptance inspection of the purchaser or his representative.

In textile mills the high artificial atmospheric humidity undoubtedly increases the tendency to rot in pine of small natural resistance to fungus. The weaving rooms of cotton mills are frequently maintained at a saturation of moisture of 70% to 80%. With 70% saturation and a temperature of 80° F., a decrease in temperature of 12° or more would cause precipitation. This condition can be found in the winter at roofs, windows, or the bearing ends of beams in walls if the heat insulation is not very complete.

Dry Rot fungus will grow on the surface of wood at atmospheric saturations from 96% to 100%, as shown by Falck.¹ It will grow inside of large beams of susceptible material at a much lower atmospheric saturation. In one case investigated the room was maintained at less than 70% and the second floor beams which were not exposed to outside temperatures were attacked. Experiments tending to show that the dry rot fungus is able to form sufficient water for its requirements in beams of large size by decomposition of the wood, are given by Mez.² Wet spots frequently remain several days on the freshly sawed surfaces of beam sections, containing living fungus. See Fig. 3. There is no question whatever about its growing inside of factory beams of non-resistant material for two or three years at least after the factory is built, with less than 70% of atmospheric moisture and in rooms where water is not used in manufacturing processes, as this condition has been found in several of the worst cases investigated.

Hard pine timber will be considered in the following pages as this is the only lumber much used for heavy mill frames. Spruce is sometimes used for floor plank. This material is probably more susceptible to rot than the better qualities of hard pine. In the only case investigated where spruce was concerned the disease evidently spread from pine beams to the spruce floor planking. In a few cases hemlock without anti-septic treatment, used as under floor in a basement, has failed in a few years. Hemlock, oak and white pine beams have failed by rot after longer or shorter service but the use of these materials for mill construction is not sufficiently frequent to require more than passing mention.

Twenty-six varieties of hard pine are described by Penhallow,³ as growing in North America. Of these only four are much used for timber in the Eastern states. The four timber varieties,

1. Hausschwammforschungen, Vol. 6, page 308; Moeller, Jena 1912.
2. Der Hausschwamm, Dr. Carl Mez; Dresden 1908, page 192.
3. A Manual of the North American Gymnosperms, D. P. Penhallow, 1907

the longleaf (*Pinus Palustris*), shortleaf (*Pinus Echinata*), Cuban (*Pinus Heterophylla*), and North Carolina (*Pinus Taeda*), are very fully described in "Timber Pines of the Southern States," by Mohr.¹ The longleaf pine is much more valuable for lumber than the others from its greater strength and durability. The latter quality is probably chiefly the result of the high percentage and uniform distribution of the rosin and the small percentage of sap wood, the sap wood of the longleaf pine averaging not over two inches in radius of mature trees, while that of the other three varieties varies from 4" to 6" of the radius.

Many of the specifications for hard pine are vague or meaningless owing to the fact that the terms used are not clearly defined or are not determinable. For example, "best quality" could honestly be taken to mean the best in the local market, or the best in the world.

"Longleaf pine" is practically impossible to identify beyond a doubt in the form of lumber, and in fact it is now rather the exception than the rule to find this variety of pine in the large sizes required for mill beams. Other varieties are regularly accepted as "Longleaf."

"Georgia" is sometimes added to a specification but lumber grown in that state is seldom insisted upon, nor is its place of growth important.

The Interstate Rules for Yellow Pine lumber for 1905 define Prime Quality, Dimension Sizes, as follows: "All square lumber shall show two-thirds heart on two sides, and not less than one-half heart on two other sides. Other sizes shall show two-thirds heart on face and show heart two-thirds of length on edges, excepting when the width exceeds the thickness by three inches or over, then it shall show heart on the edge for one-half the length."

1. Timber Pines of the Southern States, Charles Mohr, Bulletin No. 13, U. S. Department of Agriculture, Division of Forestry, 1897.

Merchantable Inspection. "All sizes under nine inches shall show some heart entire length on one side. Sizes nine inches and over shall show some heart the entire length on two opposite sides," etc.

The specification for prime quality loses most of its force when applied to pine of the type shown in Fig. 4. The young heart wood has rotted nearly or quite as rapidly as the sap wood. Most of the beams shown in Fig. 6 are of this variety. Timber of merchantable inspection in addition to the uncertainty of the heart wood mentioned above has the practical certainty of rot in the sap wood if conditions are not most favorable. This grading is particularly treacherous with the deep, narrow sections frequently used for double beams.

The average number of annual growth rings per inch has been suggested as a criterion for selecting good hard pine lumber, as follows:¹ first quality should have fifteen or more rings per inch, as an average of five inches across the grain; second quality should have an average of from eight to fifteen growth rings, and material having less than eight should be considered unfit for structural use. This would admit such material as that shown in Fig. 4 and exclude such as that shown in Fig. 5. The dense, coarse-grained, resinous, Cuban heart wood is as strong and durable as the longleaf pine, its bad quality being that it has a large percentage of not very clearly marked sap wood which is rapidly destroyed by fungus. See Fig. 2.

A later suggestion which has been adopted by the American Society for Testing Materials² calls all good material "longleaf pine" and poor material "shortleaf pine." This is unfortunate in giving an arbitrary meaning to the names longleaf and shortleaf, which already have a generally accepted botanical meaning and is incomplete in not defining the qualities of the two classes.

The positive identification of longleafed pine lumber is difficult or impossible. There are slight microscopic differences in the form of the medullary rays of the North

1. American Society for Testing Materials Proceedings, 1909, page 291.

2. American Society for Testing Materials Proceedings, 1912.

Carolina pine, as given by Penhallow¹ and Roth,² but to use them for identification would require considerable experience in the microscopic study of the pines. The macroscopic differences are more striking with characteristic specimens. The longleaf pine is heavy, resinous and fine grained, averaging for the dry wood from the butt of the tree, according to Sargent,³ 43.6 lbs. per cubic foot. See Fig. 1. The Cuban pine is slightly heavier, averaging 47 lbs. per cubic foot, resinous and coarse grained, with a large proportion of dense summer wood and a much larger proportion of sap wood. See Fig. 2, also Fig. 5. The North Carolina pine is lighter, averaging 34 lbs. per cubic foot, somewhat less resinous, coarse grained, with a small percentage of summer wood. See Fig. 3. The shortleaf pine is moderately light, averaging 38 lbs. per cubic foot, the least resinous of the four and of medium coarse grain. The following are the weights per cubic foot given by Mohr for kiln dried material,—longleaf 36 lbs., Cuban 37 lbs., shortleaf 30 lbs. and North Carolina 31 lbs. The reason for Mohr's weights being less than those of Sargent is that he takes the average of the tree, the top of which is much lighter, while Sargent considers only the heart wood at the butt.

There is considerable confusion in local names. Mohr gives six Latin and twenty-nine common names as having been used at different times or different places for the longleaf pine; the other varieties have nearly as many. The Cuban and longleaf pines are sometimes confused as both have long leaves, while the shortleaf and the North Carolina have short leaves.

1. North American Gymnosperms, D. P. Penhallow, 1907.
2. Bulletin No. 13, U. S. Division of Forestry, 1897, page 143.
3. Silva of North America, C. S. Sargent, 1897.

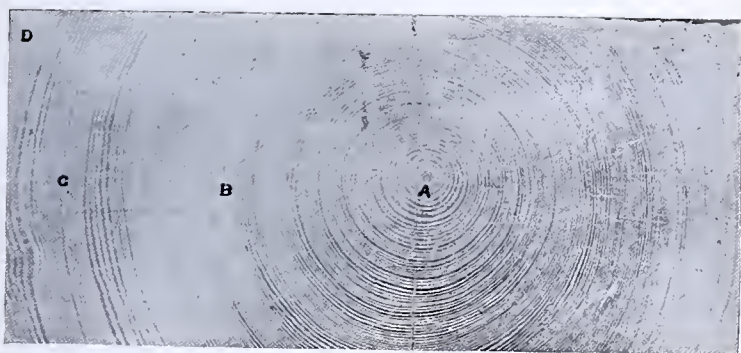


FIGURE 1. LONGLEAF PINE, 8" x 18".
DISTRIBUTION OF ROSIN: A 25%, B 14%, C 17%, D Sap Wood 3%.

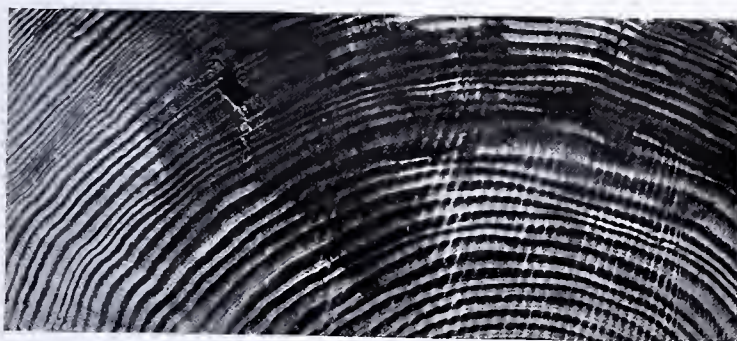


FIGURE 2. CUBAN PINE, 8" x 18". INFECTED WITH FUNGUS.



FIGURE 3. NORTH CAROLINA OR LOBLOLLY PINE, 8" x 18",
CONTAINING LIVING FUNGUS.

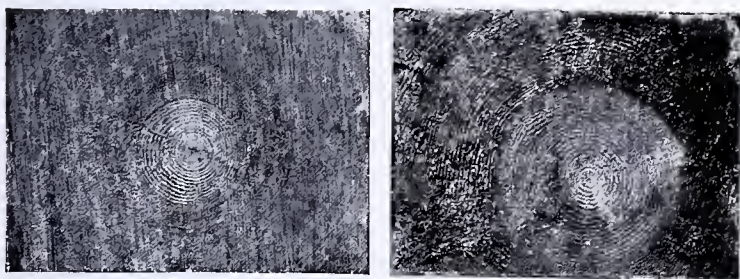


FIGURE 4. SOUND AND ROTTED SECTIONS OF 12" x 14" BEAMS;
PROBABLY SHORLEAF PINE.

A treacherous type of hard pine is shown in Fig. 4. This material is probably shortleaf pine, although it may be longleaf grown under unfavorable conditions. The percentage of rosin and the gravity is somewhat higher than that given by Mohr¹ for shortleaf, but the arrangement of growth rings corresponds with his description. It is very common, hardly a lot of lumber is to be found of which this does not form a considerable proportion. Most of the rotted beams shown in Fig. 6 are of this type. It is characterized by coarse grain at the center, generally consisting of four to six growth rings per inch, becoming regularly finer with increased diameter until at six or eight inches from the center there are twenty to thirty growth rings per inch. The rosin and resistance to rot decrease with the rings. At the center there is generally in the neighborhood of ten per cent of rosin; at four or five inches from the center there is frequently less than three per cent. The line between the heart and sap wood is well marked, the heart being much darker than the sap, as with the longleaf. This material is regularly sold as longleaf

Tannin in the heart wood is said to retard fungus growths in oak.² The resistance to fungus caused by rosin is the important factor in the valuable qualities of the hard pines. The follow-

1. Bulletin No. 13, U. S. Division of Forestry, page 13.

2. Berichte d'Deutschen Botanischen Gesellschafts. Vol. 29, Mycologisches Centralblatt, Vol. 1, 1912, pages 138 & 166.

ing experiment was made to show the effect of rosin. A block of longleaf pine two inches on a side, containing 18% of rosin, was sawed in two across the grain. Half of it was boiled in benzole and after the removal of the rosin the benzole was driven off. Both pieces were cultivated in contact with wood containing living dry rot fungus. At the end of a year the specimens were dried and weighed. That from which the rosin had been removed had lost 8% in weight, the other only 2%, showing that the rosin had decidedly retarded the action of the fungus under conditions otherwise identical.

Cuban pine is the heaviest and frequently the most resinous of the timber varieties. Fig. 5 shows a section of a beam weighing 72 lbs. per cubic foot. It can be seen that besides being saturated with rosin this is nearly all dense summer grown wood.



FIGURE 5. 8" x 12" BEAM WEIGHING 72 LBS. PER CUBIC FOOT.

The ideal specification is undoubtedly a clear description of the qualities required. In structural timber these are strength and durability. With these qualities defined, attributes, such as botanical variety, location of growth or grading, lose their importance. The limits of strength can be easily given but

less easily determined, without destroying the material. The density is probably a sufficiently close index of strength for commercial purposes. A sufficiently reliable index of durability is the percentage of rosin.

Both the rosin and the density can be conveniently found by boring half inch holes into the end of the beam, collecting the chips, drying and weighing them, then extracting the rosin from them with benzole and weighing it. Cuban or North Carolina pine with 10% of rosin is apparently as resistant to fungus as longleaf pine with the same percentage. Heart without rosin is not a saving quality.

The percentage of rosin in the sound centers of rotted beams taken from a mill was determined in order to get an idea of the amount required to stop fungus growth under ordinary mill conditions. See Fig. 6. With the poorest of hard pine there is generally a sound center to rotted beams and this center contains more rosin than the remainder of the section. Sometimes it is not bounded by the growth rings but is very irregular, the cause being that rosin has been irregularly deposited in the section owing to knots or injuries to the tree. The limits of the sound center are frequently not the same as those of the heart wood.

It is apparent that the limiting amount of rosin which is just sufficient to stop the fungus is in the neighborhood of three per cent. The limiting power of rosin is undoubtedly not absolute but varies with the moisture, variety of fungus and time of exposure. Therefore, it is safe to assume that a mill beam should have not less than five per cent of rosin throughout to successfully withstand fungus from its own power of resistance under ordinary conditions of dampness, allowing a factor of safety of about two. Dye houses and paper mills would probably require more.

In order to determine the distribution of rosin in timber of average good quality now being supplied for factory construction, several sections from beams recently bought to replace others which had rotted were analyzed. Part of these are shown in Fig. 7. The large holes were for samples for rosin analysis, and the small ones for density determinations. The material was mostly heart wood and the price paid for it was \$59 per thousand feet board measure. None of the sections have 5%

of rosin throughout. Three would come within this limit by cutting off about 10% and the remaining five would require a reduction of about 75%.

If it can be logically assumed that better material could be bought by increasing the price in the proportion of the reduction of the cross section necessary to get the required 5% of rosin, a price of \$115 per M. would be indicated. From such figures as I have been able to obtain I should think this price is not far out of the way for such selected material in large sizes and at the price it is doubtful if a sufficient amount for a factory could be had in the required sizes. This indicates that hard pine with sufficient natural resistance to withstand fungus unassisted is out of the question at prices that compare favorably with other forms of construction.

Ventilation is generally the first preventive measure suggested. Low power of resistance in the timber is frequently the last cause to which a serious dry rot outbreak is charged. Dry wood which is kept dry is undoubtedly incapable of fungus infection but ventilation does not necessarily cause drying. The wood will come into equilibrium with the moisture in the air and will become dryer or wetter in proportion to the relative humidity. Therefore timber ventilated with moist air will have its rate of rotting accelerated if it is a susceptible variety. Moreover the susceptible varieties absorb moisture more rapidly than those which are more resistant.

A heavy coat of paint may accelerate or retard the rate of rotting, depending upon whether it prevents wood from absorbing or giving up moisture. The question of primary importance is whether the wood is resistant or susceptible.

ROTTED 12" x 16" PINE BEAMS REMOVED AFTER TWO YEARS' SERVICE.



FIGURE 6. PER CENT ROSIN.

A	B	C	A	B	C
5.36	7.04	.68	29.21	12.17	.88
4.46	1.99	.76	6.26	6.56	.58
8.36	4.89	1.17	3.45	18.81	.99
7.72	5.12	.83	9.45	2.31	.82

NEW SELECTED 12" x 16" BEAMS.

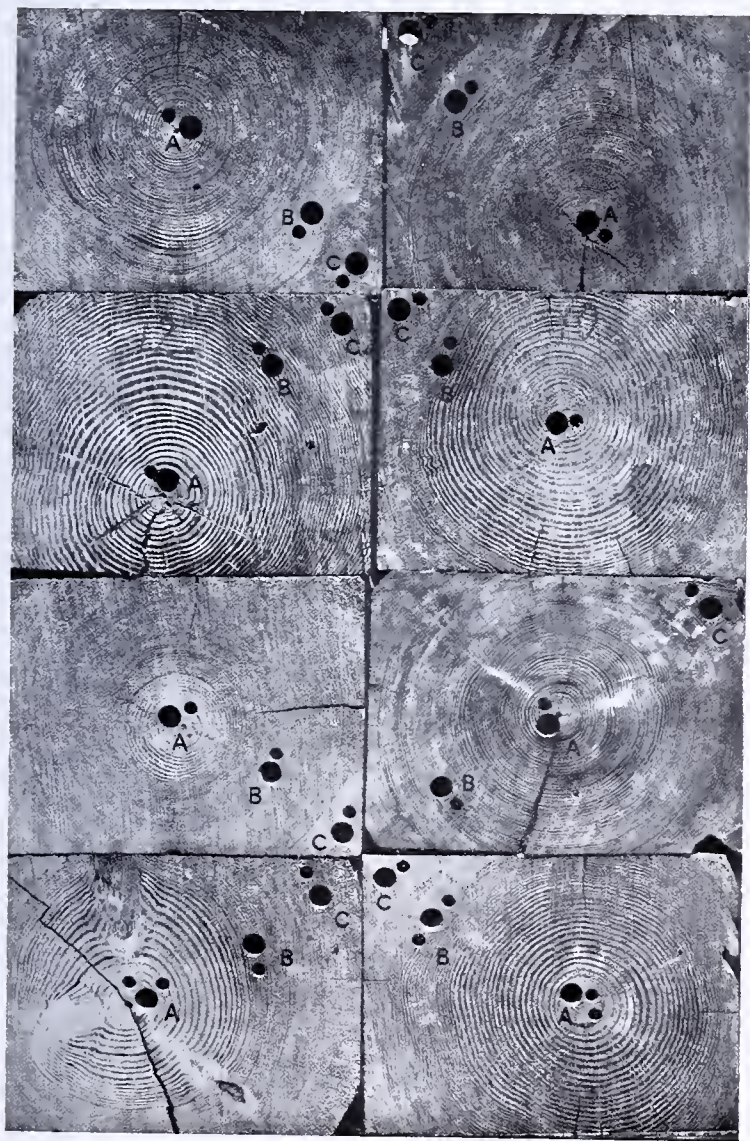


FIGURE 7.

PER CENT ROSIN.						LBS. PER CU. FT. AIR DRY.					
A	B	C	A	B	C	A	B	C	A	B	C
13.1	14.1	2.6	7.5	11.3	1.1	40	44	34	42	55	50
34.7	14.1	2.6	12.3	3.0	2.4	46	57	61	39	45	36
12.2	2.4	2.9	8.6	3.2	.8	36	39	37	37	42	33
14.6	2.7	1.6	12.3	3.0	2.4	37	42	37	34	36	30

Fungi are frequently carried in lumber¹ and spread to other susceptible material by placing it in large piles with scant ventilation. As a result of this beams are found more deeply infected in the middle than at the ends. Sticks containing living fungus used for separating the lumber in the piles is another fruitful source of infection. Susceptible timber placed on rotten supports near the earth quickly becomes diseased. This is avoided in one lumber yard by use of concrete supports as shown in Figure 8.



FIGURE 8. CONCRETE SUPPORTS FOR LUMBER PILES.

The distribution of moisture in the air of apparently well ventilated spaces is irregular. In a recent case fungus appeared on the floor beams under a weave shed about 300 ft. wide within a year after the building was completed. The beams were about four feet above a damp swampy soil. The builders appreciating that the conditions were unfavorable gave the beams a brush treatment with a coal tar preservative and provided large open windows at frequent intervals for ventilation. The beams evidently contained living fungus when received. The ventilation prevented growth of the fungus on the surface of the wood for 50 or 60 feet from the windows. Beyond this an abundant growth appeared. Measurements showed the percentage humidity to be nearly 100% in the middle of the building, and 60% at 40 ft. from the windows.

1. Bulletin No. 13, U. S. Division of Forestry, page 118.

Holes through columns and narrow openings between beams encourage fungus more frequently than they prevent it. One of the reasons given for bored columns and double beams has been to prevent dry rot and considerable importance has sometimes been given to this feature.¹ Undoubtedly columns with holes through them and thinner beams would dry out quicker if given a chance to season, but the common custom of boring green or wet columns just before they are put in place in the building and using moist lumber for double beams leaves ideal places for the growth of fungus as the air in the openings is saturated with moisture. The holes in the columns have the additional objection of forming a convenient passageway for the fungus to pass rapidly from floor to floor before the building has dried out. Figure 10 shows a section of a bored pine column split in two with fungus growing through the hole although the column was not deeply attacked, as can be seen from the photograph of the cross section, Figure 9. The hole is inefficient in preventing rot if the material of the column is susceptible, as can be seen from Figure 11, which shows a section of a bored column badly rotted. Figure 12 shows fungus growing in the opening between double beams, the front half of the beam having been removed.

Untreated Carolina pine used for interflooring sometimes serves not only to infect the mill but to carry the infection to all susceptible beams or planking in the floor.

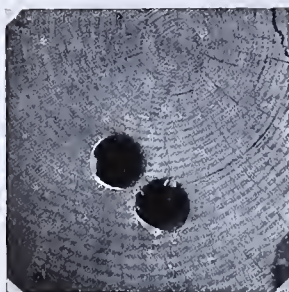


FIGURE 9.

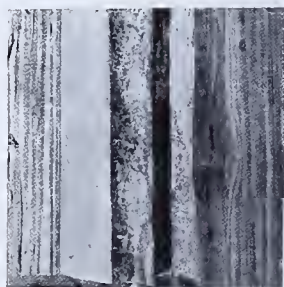


FIGURE 10.

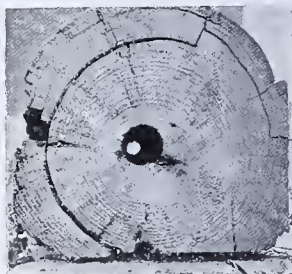


FIGURE 11.



Many old mills are to be found with hard pine timbers sound after years of service in moist air. A careful examination of these timbers will generally reveal the fact that they are resinous longleaf pine, no longer practicably obtainable. There is no more reason for supposing that the nonresinous hard pines now in common use will prove resistant than there would be for expecting moist hemlock or birch to resist fungus. There is still available sufficient hard pine for present requirements, of suitable size and strength for mill construction. It simply remains to supplement its waning natural resistance with proper antiseptic treatment.

The dry rot disease is widely distributed in this country, although it has been more carefully investigated in Europe, especially in Germany. Forty dry rot cases have been brought before the German courts within the last ten years.¹ In past years little importance has been given to the disease in this country, but the occasional cases recorded² indicate that it was more a question of the general use of material of high natural resistance than the absence of the disease. The fact that it has shown itself in widely separated parts of the country at about the same time on susceptible material adds weight to this theory. Within the past three years well defined fruiting plants of the *Merulius Lacrymans* or *Coniophora Cerebella* have been found in Massachusetts, New Hampshire, Chicoutimi, P. Q., Montreal, P. Q. and Hamilton, Ont.

A half dozen varieties of fungi are the cause of most of the damage to buildings although hundreds of them can grow on wood under favorable circumstances. The conditions of germination and growth of the *Merulius Lacrymans* or dry rot fungus have been mysterious. The spores germinate in an eccentric manner and frequently refuse to grow to fruition on their customary host in artificial cultures. Hartig stated that an alkaline medium is necessary. It has since been shown by several investigators that an acid medium is required for the growth of the plant, but that the degree of acidity and the kind of acid is important. Falck shows that acetic, formic or carbonic acids are poisonous to it while malic, citric and tartaric, favor its growth. Malic in 5% concentration with 5% of malt

1. Hausschwammforschungen. Vol. 2, 1908 & Vol. 5, 1911.

2. Charles T. Main. Notes on Mill Construction, page 31.

extract has been found to be a favorable medium for artificial cultivation. Acid phosphate of ammonium also favors the growth. By a very careful series of experiments Falck has shown that a moderately **low temperature (75° F.) is necessary for the most rapid growth of Merulius Lacrymans, and it is killed in a few hours at 110° F.** He solves the mystery of its refusing to grow on blocks of sound wood, which are its usual host, by showing that the wood in its natural state is not sufficiently acid for this fungus, and that it must first be attacked by another fungus such as *Coniophora Cerebella* or *Polyporus Vaporarius*. These fungi in passing through the wood render it sufficiently acid for the rapidly growing *Merulius Lacrymans* which later take possession to the exclusion of the earlier and less powerful invader.

Fruiting fungi can be easily identified, but it is difficult or impossible to positively identify the young sterile growth. The chief use in identification is to help in determining the best curative measures to apply. For example the *Lenzites* can stand high temperatures, nearly up to the boiling point of water, according to Falck,¹ while the dry rot family are killed at a comparatively low temperature. The *Lenzites*, however, are not often found in mill timbers unless the conditions are exceedingly moist. I have found only one of this variety, this being on a ceiling of North Carolina pine near a leaky steam pipe.

Dry rot fungi has two methods of reproduction and can remain a long time in a resting state. The common reproductive body, corresponding to the seed of higher plants, is called a spore and grows over the surface of the plant. They are of brown color and therefore may be easily distinguished from the surrounding sterile growth, as can be readily seen from Figures 14 and 15. The spores are microscopic in size, being about .0004 of an inch long and .0002 of an inch broad. A single plant produces many millions and their small size allows them to float long distances in the air.

Another reproductive form is assumed by the fungus when brought under unfavorable conditions for growth, such as insufficient moisture. In this form the growing plant separates

1. Hausschwammforschungen, Vol. 3.



FIG. 14. *MERULIUS LACRYMANS* OR DRY ROT WITH FRUIT.



FIG. 15. *CONIOPHORA CEREBELLA* WITH FRUIT.

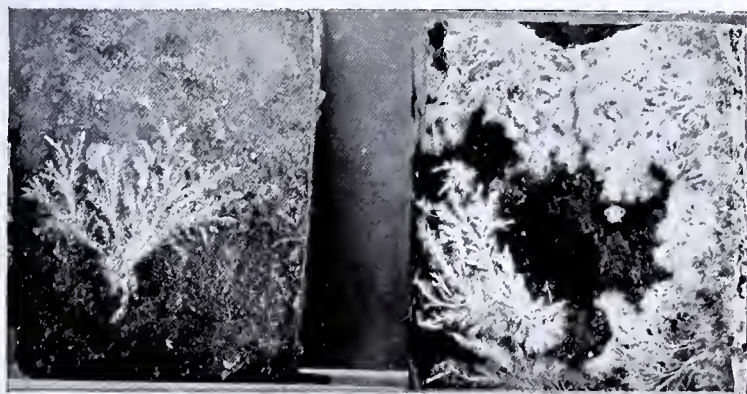


FIG. 16. STERILE DRY ROT PLANTS AS COMMONLY SEEN.

into small sections which can sprout and grow again when favorable conditions arise. It can remain in this resting state for a considerable time in air dry wood.

I have some specimens from a beam which was removed from a mill two years ago. Cultures from time to time show the *Merulius Lacrymans*, which it contains, to be still living. Mez¹ mentions a case in which it remained alive for four years and eight months in a dry museum cabinet.

Many varieties of moulds grow readily on moist pine sap wood, as can be seen in Figure No. 13, showing blocks which have been cultivated by being soaked with water six hours and left in fruit jars. H. Marshall Ward mentions one of the common moulds (*Penicillium*) as a wood destroying fungus.² It is probable that few of the moulds are important in this connection but they serve to show clearly whether or not a wood is susceptible to fungus attacks.



FIGURE 13.

1. Der Hausschwamm, Dr. Carl Mez. 1908, page 63.
2. *Penicillium* as a Wood Destroying Fungus, H. Marshall Ward. *Annals of Botany* 1898, Vol. 12, page 565.

The *Polyporus Vaporarius* is frequently found in basement floors or other moist woodwork. It is characterized by a milk white color, and when in fruiting state, a porous surface. This is not often the cause of destruction of factory timbers above the basement, although in one case a weave shed roof which was put on wet and kept moist by the high humidity was seriously damaged probably by this fungus.

Wood which is thoroughly infected frequently gives little warning of its condition even when cut, as can be seen by Figure 17, which is four sections of an 8" x 18" beam 22 ft. long. This appears from microscopic examination to be permeated with fungus although it shows none of the familiar signs of rot and its strength is not yet seriously reduced. The only sound wood is at the center of growth and about 4" in diameter. The first six or eight years growth contains about 25% of rosin, while the remainder of the section has less than 2%.



FIGURE 17. WOOD INFECTED WITH FUNGUS.

A cheap and sure cure for dry rot infection has not yet been discovered. Several remedies may be used with more or less success in cases which are not too far advanced. In serious cases where much of the building has been involved, the only practicable treatment is to remove the infected material and carefully sterilize the surrounding woodwork or masonry.

Creosote or a 1% solution of corrosive sublimate (Bichloride of mercury) can be conveniently used for this purpose. The corrosive sublimate can be dissolved in wood alcohol with advantage when it is necessary to treat wet wood. A better penetration is obtained with alcohol than with water or with oily substances like creosote. A 1% solution of corrosive sublimate has been used with apparent success for washing a ceiling infected with surface moulds, also for treating mill beams where dry rot has shown itself superficially in a few places soon after the completion of the building. In this case the alcohol solution was injected into the beam by boring small holes at intervals of 18" and keeping them filled as long as the wood continued to absorb. The perforation of the wood cells by the fungus increases the penetration. Experiments by the United States Department of Forestry in preventing bluing by fungus in pine sap wood have shown corrosive sublimate in dilute aqueous solution to be efficient.¹

Great care must of course be used in handling corrosive sublimate as it is a powerful poison. It is stated that when once in the wood cells it forms insoluble compounds with the albuminous components. Most of the wood preservative materials are more or less poisonous. The smell of creosote serves as a warning, but the poisonous constituents are volatile.

Wood destroying fungi cannot grow under water or with the wood cells filled with water. Penstocks have sometimes been covered with clay to prevent evaporation and



FIGURE 18. $2\frac{1}{2}$ " PLANK FROM A WATER TANK.

1. U. S. Dept. Agriculture, Forest Service, Circular 192.

The Prevention of Sap Stain in Lumber, H. F. Weiss and C. T. Barnum, 1911.

keep the cells full of water. Figure 18 shows a plank from the bottom of a tank in which the fungus grew through a narrow space in the middle, the inside next the water being too wet for it and the outside next the air too dry.

Wood of great antiquity has been found buried in clay in a perfect state of preservation.¹ Piles under an old London bridge were found sound after being in the water 600 years.² The roof beams of the Basilica at Rome were found sound after a thousand years use under conditions of dryness.³

Pure oxygen retards the rate of growth of dry rot, according to the experiments of Falck.⁴ The same author finds that strong light also acts unfavorably on the growing plant.

Heat and dryness will kill dry rot, and it is particularly sensitive to heat, a temperature of 108° F. for three hours or 115° F. for one hour being sufficient to kill it.⁵ It is also killed by complete dryness according to Falck.⁶ Ordinarily air drying, however, does not destroy it.

Heat as a means of destroying dry rot in mill beams was tried recently at the suggestion of the writer on a large mill which was badly infected throughout. The removal of a thousand beams and columns later gave an excellent opportunity to test the efficiency of the treatment by cultivating samples from those where the infection was the deepest. The mill was heated four times to about 115° F., by use of the steam heating system in warm weather, from Saturday noon time until Monday morning, the temperature being carefully regulated by use of thermometers placed at the ceiling. In use of heat in mills with automatic sprinklers, care must be used not to open or permanently injure the sprinkler heads by keeping at least 50° below their melting point.

Specimens were cultivated from forty of the badly rotted beams and only four showed living fungus. One hundred and three beams removed and left on the ground for several months were examined superficially, and only six showed suspicious threadlike growths. The window frames and hollow roof were not sterilized by this treatment. Some of the living cultures came from the ends of beams which were imbedded in the brick

1. North American Gymnosperms. Penhallow.
2. Destruction of Wood by Fungi, Buller, Science Progress. Vol. III, No. 2.
3. A Treatise on the Resistance of Materials, D. V. Wood, 1883.
4. Hausschwammforschungen, Vol. 6.
5. Hausschwammforschungen, Vol. 1.
6. Hausschwammforschungen, Vol. 6.

work where the heat could not readily penetrate, and the beams left on the ground may have been reinfected.

Beams removed from the mill before it was heated showed vigorous growth on cultivation as well as the formation of normal fruit when left lying in the yard.

While the results of this experiment are not absolutely conclusive, they are very encouraging and indicate that the small cost of putting steam on the heating coils is well worth trying, if there is any suspicion of dry rot in a new building. Heating will probably prove more efficient in the few scattered superficial infections of a mill just completed than it did in this mill where the growth had been in active progress for two years or more and had deeply penetrated the susceptible material. The heat will also increase the rapidity of drying and thereby tend to limit the spread of the disease through the agency of the rapidly growing threadlike plants. These growths pass rapidly along the splines of moist floor planks and through holes in moist columns or openings between double beams and can thereby quickly reach most of the susceptible material in the building. The most serious cases investigated have been where sappy or nonresinous material was subjected to excessive moisture and covered in a 'watersoaked condition.

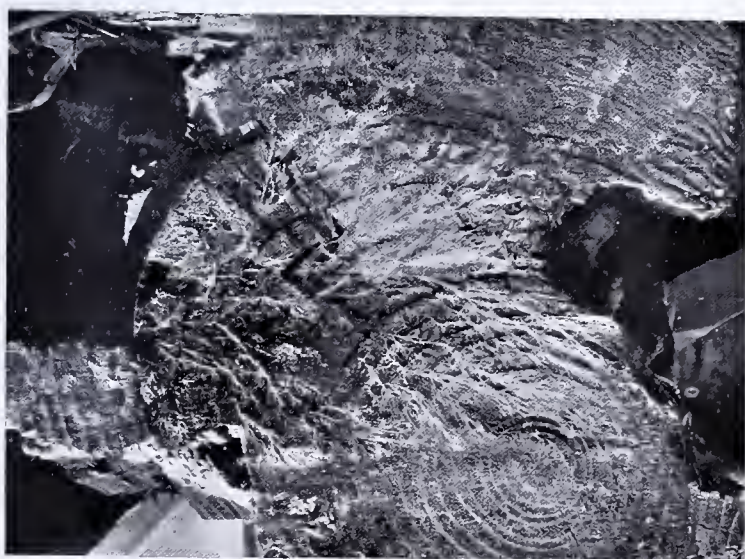


FIGURE 19.

Formaldehyde vapor has been suggested by Falck¹ as an efficient cure, the method of application being the same as that used for disinfecting houses from contagious diseases. The same authority states that carbon dioxide gas is a sterilizing agent. I have never tried either of these remedies but it seems as though it would be difficult to cause the vapor or gas to sufficiently penetrate large mill beams to do much good in a reasonable time.

With the most carefully applied curative treatments there is always an element of uncertainty. The disease has always penetrated much further than it is supposed to have and may have so weakened the columns or beams that a slight shock or fire can cause the building to fall as in the case of the Gledhill Wall Paper Factory in New York City.² There is generally a shell of from $\frac{1}{2}$ " to $\frac{3}{4}$ " in thickness of sound wood on the outside of beams or columns in moderately dry rooms. On striking such a beam which externally appears to be sound with the round face of a machinist's hammer, the shell may be penetrated and the hammer sink into the wood.

Antiseptic treatment of building material before it is put into the structure is the only practicable solution of the problem. Much attention has been given in this country to the treatment of railroad ties, posts or other material intended for use near or in contact with the earth. But little study has been given to mill timber. The well known natural resistance of longleaf pine has been considered sufficient to guarantee the permanence of structures. This is undoubtedly sound judgment when good quality longleaf pine is used, as the older mills have clearly shown. The several varieties of pines now commonly used for heavy mill frames do not have this natural resistance. Their use has become a necessity. With antiseptic treatment and reasonable compensation for the difference in strength, the quicker growing varieties should fill the requirements of the future as satisfactorily as the longleaf has done in the past, but the use of these sappy quick-growing varieties without antiseptic treatment is being followed by disaster.

1. Hausschwammforschungen, Vol. 6, 1912, page 343

2. Engineering News. Vol. 62, 1909, page 620.

What antiseptic treatment shall be used is an important question. Numerous compounds have been proposed. The problem of treating mill timber is different from that of railway ties and posts. Increased fire hazard, resistance to paint and the disagreeable odor are of no importance with ties or posts, but of great importance with factory timber. Moreover, the leaching action of rain or ground water is important with posts and ties and of no importance in buildings where the material is protected from the weather. For this reason, the numerous creosote and tar compounds in extensive and successful use with ties are less suited, to treating factory timber. The metal salts are preferable from evidence thus far available.

The fungus=destroying power of various antiseptics has been carefully studied by several investigators. The following table is given by Falck.¹ This not only gives the relative toxic power of the several materials but the comparative value. The results are derived from laboratory experiments on germinating spores and fungus grown on various media. This must be given due consideration in estimating the practical value of the materials as preservatives. The only tests which can be considered final are those which are carried out over long periods of time under the conditions of actual service. Toxic materials may be either volatilized and removed, chemically changed and thereby made inert or they may combine with reactive parts of the wood.

By "inhibition concentration" is meant that strength which is just sufficient to destroy the fungus under investigation.

1. Hausschwammforschungen, Vol. 6, page 377.

Material.	Inhibition Concentration. Parts in a thousand.	Price per pound multi- plied by Inhibi- tion Concentra- tion.
Phenol, C_6H_5OH	1.	50
Dinitro-o-Cresol $NaC_6H_2(NO)_2CH_3ONa$	.05	56
2:4 Dinitrophenol $NaC_6H_3(NO)_2OH$	.05	10
Silican Magnesium Fluoride, $MgSiF_6 + 3H_2O$	1.	100
Acetic Acid $C_2H_4O_2$	1.	82
Salicylic Acid $C_7H_6O_3$	1.	305
Boracic Acid H_3BO_3	2.	114
Corrosive Sublimate, $HgCl_2$	1.	520
Sulphate of Copper, $CuSO_4 + 5H_2O$	10.	550
Chloride of Zinc, $ZnCl$	5.	215
Sulphate of Iron, $FeSO_4 + 7H_2O$	20.	280
Salt, $NaCl$	100.	1000

As a result of his careful investigations of a large number of different proposed toxic materials, Falck recommends the sodium dinitrophenolate which is shown to be the most powerful fungus poison in the above list. This chemical is practically unknown in this country, and no experience with it as a wood preservative is available. Its chemical formula indicates a readily combustible material although it is stated that its explosive qualities have been overcome. Experiments made in France¹ with "Antinonnine" showed it to be much less efficient than creosote as a wood preservative. This material is stated to be dinitrocresolate of potassium. From the chemical similarity it would be expected that the action of this material would not be much different from the dinitrophenolate and cresolate of soda given above.

1. Préservation des Bois. E. Henry, 1907, page 19.

Dean and Downs¹ give the toxic value of creosotes from laboratory tests as follows:

	Inhibition Concentration. Parts in a thousand.
A Coal tar creosote No. 1.....	below 1
B Coal tar creosote No. 2.....	1
C Water gas tar creosote No. 1.....	4
D Water gas tar creosote No. 2.....	3.5
E Pressed Anthracene Oil.....	above 8.5
F Sample A minus the Phenols.....	3
G Sample A minus the Phenols & Tar bases,	6

Materials which are in no sense poisonous can resist fungus successfully as in the case of the wood cells filled with water. It is probable that the beneficial results from rosin and some of the tars is caused by their waterproofing qualities. On the other hand well known bacterial antiseptics may be worse than useless for treating wood, as was shown by use of chloride of lime on timber.² The chloride of calcium left in the wood cells attracted water and the building was quickly destroyed.

The absence of suitable food material has been put forward as an explanation of why certain woods are immune to fungus. Experiments by the writer with stachyboetris on flax show the luxuriance of growth to be a direct function of the amount of nitrogenous material present. The permeability of wood to water is an important feature.

1. Antiseptic Tests of Wood Preserving Oils, Dean & Downs, Journal of Industrial and Engineering Chemistry, Vol. 5, page 126, 1912.

2. Atti del Reale Istituto Veneto di Scienze Lettere ed Atti, 1904, Vol. LXIV, Parte 1.

Coal tar compounds are probably more used as anti-septics for treating wood than all other materials together. They act mechanically and chemically serving as waterproofing as well as antiseptics. There has been more or less controversy as to the value of carbolic acid, naphthaline and other constituents.¹ Most of the tar products used are by-products of the gas industry, and it is not a question of the most toxic material but of the most toxic material with reasonable consideration of cost and permanence.

Coagulation of the albuminous compounds of the wood is frequently mentioned in the literature of wood preservation as an important factor. Confusion exists as to the difference between simple coagulation by boiling, and combination with an antiseptic material. The former action could serve to sterilize already infected wood. This is one of the valuable results of kiln drying but it in no way prevents later infection. A permanent combination of the antiseptic material with the wood can serve to prevent later infection. Bolton¹ is of the opinion that combinations between carbolic acid or naphthaline and wood albumen are of little importance as the compound is easily broken up by water. He regards carbolic acid of little permanent value owing to its volatility.

The reasonable price, waterproofing, and antiseptic qualities of creosote compounds as well as the satisfactory results of numerous time tests cause them to be looked upon favorably as antiseptic materials. The disagreeable odor, black greasy surface and increased inflammability are their objectionable qualities. Where waterproofing is important in basement floors or rooms with wet occupancy the objectionable qualities may not be prohibitive.

An oily antiseptic in considerable quantity on wooden ceilings can increase the fire hazard in sprinklered mills, as a fire once started can travel across the oil soaked ceiling more rapidly than the sprinklers can open, involving large areas. The high flash point of the oil makes little difference because a thin film on wood, which is a poor conductor of heat, is rapidly heated by its own combustion to a sufficiently high temperature to burn rapidly. This action is decreased with

1. Preservation of Timber, Bolton, 1885.

time as the oil soaks deeper into the wood and the more volatile parts disappear, but an oil that will permanently waterproof wood will undoubtedly permanently increase its inflammability.

Burnettizing by use of chloride of zinc is extensively used and has given generally satisfactory results for railroad ties. It is understood to be considerably less expensive than creosote. There is, however, a suspicion that it may reduce the strength of the material. The action may be slow but continuous and accelerated by moderately elevated temperatures. Such weakening would be of slight importance with a railway tie which is not called upon to resist a heavy strain. In a report on the preservation of timber by a special committee of the American Society of Civil Engineers in 1885, it was stated that Burnettized bridge timber, that is,—timber treated with chloride of zinc, was weakened 10% or more.¹ It was also stated that railway ties treated with this material gave better satisfaction kept away from light and air by a covering of earth.

Chloride of zinc is a well known solvent of cellulose. It is probable that if the timber was not deeply treated or kept at a moderate temperature it would do little harm. However, with deep penetration or higher temperature, investigation is needed as to its effect on the strength of the timber before it is recommended for important parts of a structure.

It has been stated that wood treated with chloride of zinc and set on fire continues to glow for several hours burning deeply into it in a manner similar to the punky wood which has been attacked by fungus. Mr. Hartman of the Avenarius Carbolinium Company in a private communication states that he observed this action in connection with some experiments made by heating wood treated with several antiseptic compounds in a muffle, and when it became ignited, removing it into the air. I have seen no other mention of this action. It has generally been supposed that Burnettized wood was rather less combustible than the same material before treatment.

Kyanizing by use of corrosive sublimate was patented in England in 1832. Since then it has been in limited but apparently successful use. The Locks & Canals Co., of Lowell, Mass., commenced using this process in 1848 and have kept

1. Transactions American Society of Civil Engineers, 1885, page 325.

careful records of the results. Mr. James Francis¹ stated that kyanized fence posts were in service in 1891 that were set in 1850. It is understood that some of these posts are still in service 63 years after they were set. Other timber parts of bridges where conditions are exceptionally trying remained in service 32 years. This timber, however, was carefully selected and seasoned before treatment, a condition which may have somewhat added to the efficiency of the antiseptic. The only failures of which I have been able to learn are basement floors where the planking was cut after being treated, thereby exposing the untreated center of the plank, as the penetration is only about $\frac{1}{4}$ of an inch. The method of treatment employed is to soak the material in a cold 1% solution in a masonry tank, the time of soaking being arbitrarily set at a day an inch plus one,—that is, for a beam 4" x 10", five days, and for one 6" x 10", seven days. The solution attacks iron and other metals so that it is not found practicable to use it in metal tanks. It is claimed that the mercury once in the wood enters into chemical combinations with its albuminous constituents and becomes insoluble so that it cannot be leached out.

The penetration of antiseptics has been increased by the use of vacuum and pressure processes, applied in closed tanks. Alternate heating and cooling also increases the penetration. This process is sometimes carried out by dipping the timber first into a tank of hot material and then into cold, or by boiling it for a time and then allowing it to cool. By suitable manipulation of this process in addition to obtaining considerable depth of penetration the wood cells can be left full or nearly empty, as desired. This method is based on the expansion and contraction of the air in the cells. A heating process might be used with corrosive sublimate to increase the penetration where this is necessary. It is probable that the penetration obtained by the present method with the cold bath is sufficient for mill lumber not subject to excessive moisture.

Brush treatments have some value in retarding the progress of fungus as is shown by a recent Division of Forestry publication.² A recent experience in a weave shed basement shows that

1. Methods of Preserving Timber in Situations Which Expose It to Decay. James Francis.

New England Cotton Manufacturers' Association, Oct. 1891.

2. U. S. Department of Agriculture, Forest Service, Circular 198, Sept. 1912.

it is not safe to depend on brush treatment of timber already infected, if the antiseptic material depends chiefly for its preservative effect on its waterproofing qualities.

The added cost of antiseptic treatment is not prohibitive. The price quoted by treating companies varies from \$8 to \$15 per 1000 feet board measure. Much of the treated material on the market is very poor, open grain, light weight, and of small strength. The apparent cheapness disappears when the section is increased sufficiently to get the required strength. Such material should not be used with loads based on figures given in the hand books for longleaf pine, as it is frequently not half as strong and very brittle.

There is no reason why good Cuban or North Carolina pine timber cannot be purchased and either treated on the job in a wooden or concrete trough, as is frequently done, or shipped to a commercial treating plant. In so doing it is necessary to see that the material is not watersoaked, frozen or already deeply infected with living fungus when treated. Superficial treatment of such material by brushing or spraying would have but little value. The ideal time and place of treatment is immediately after sawing at the saw mill, as much of the lumber is undoubtedly infected in the yards.

With suitable antiseptic treatment there is no reason why satisfactory material for slow-burning construction should not still be obtainable at a reasonable price.

SUMMARY

My observations thus far indicate,—

- First: The percentage of rosin in hard pine can be taken as an index of its power of resistance to dry rot.
- Second: Hard pine lumber 12" square or larger is practically not obtainable with sufficient natural resistance to withstand fungus in a moist atmosphere.
- Third: The nonresinous and sappy hard pine, which is obtainable, is not safe to use for the important parts of a building without antiseptic treatment.
- Fourth: Holes through columns, narrow spaces between beams and hollow spaces in floors or roofs are of no value in preventing dry rot, and serve to rapidly spread it to all susceptible material.
- Fifth: Heating a new building to 115° F. for twenty-four hours, or more, several times, has a value well worth its cost in preventing serious dry rot damage.
- Sixth: Of the various antiseptic treatments in practical use at present, corrosive sublimate appears to be the best adapted to mill timber. Modification of the present process may be necessary when deeper penetration is required.

F. J. HOXIE,
Engineer and Special Inspector.

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THE ASSOCIATED FACTORY MUTUAL FIRE INSURANCE COMPANIES.

1 MANUFACTURERS MUTUAL F. INS. CO.,	<i>Providence,</i>	JOHN R. FREEMAN, Pres.
2 RHODE ISLAND MUTUAL F. INS. CO.,	<i>Providence,</i>	JOHN R. FREEMAN, Pres.
3 BOSTON MFRS. MUTUAL F. INS. CO.,	<i>Boston,</i>	J. P. GRAY, Pres.
4 FIREMEN'S MUTUAL INS. CO.,	<i>Providence,</i>	F. W. MOSES, Pres.
5 STATE MUTUAL F. INS. CO.,	<i>Providence,</i>	JOHN R. FREEMAN, Pres.
6 WORCESTER MFRS. MUTUAL INS. CO.,	<i>Worcester,</i>	W. E. BUCK, Pres.
7 ARKWRIGHT MUTUAL F. INS. CO.,	<i>Boston,</i>	R. W. TOPPAN, Pres.
8 BLACKSTONE MUTUAL F. INS. CO.,	<i>Providence,</i>	WM. B. MCBEE, Pres.
9 FALL RIVER MFRS. MUTUAL INS. CO.,	<i>Fall River,</i>	C. S. WARING, Pres.
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11 WHAT CHEER MUTUAL F. INS. CO.,	<i>Providence,</i>	FRANK L. PIERCE, Pres.
12 ENTERPRISE MUTUAL F. INS. CO.,	<i>Providence,</i>	JOHN R. FREEMAN, Pres.
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14 HOPE MUTUAL F. INS. CO.,	<i>Providence,</i>	FRANK L. PIERCE, Pres.
15 COTTON AND WOOLEN MFRS. M. I. CO.,	<i>Boston,</i>	BENJ. TAFT, Sec.
16 AMERICAN MUTUAL F. INS. CO.,	<i>Providence,</i>	JOHN R. FREEMAN, Pres.
17 PHILADELPHIA MFRS. M. F. INS. CO.,	<i>Philadelphia,</i>	E. I. ATLEE, Pres.
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The Associated Factory Mutual Fire Insurance Companies were organized more than fifty years ago, by certain prominent manufacturers of New England, for the purpose of providing insurance at actual cost. They confine their business almost exclusively to large isolated manufacturing properties. They have improved the construction of buildings, introduced better fire protection, and each risk is subject to regular expert inspection. They insist upon complete sprinkler protection, fire pumps, and ample water supply from at least two independent sources.

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